High Resolution Spectroscopy of SN1987A's Ring:
He I λ10830 and Hα from the Hotspots

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INTRODUCTION

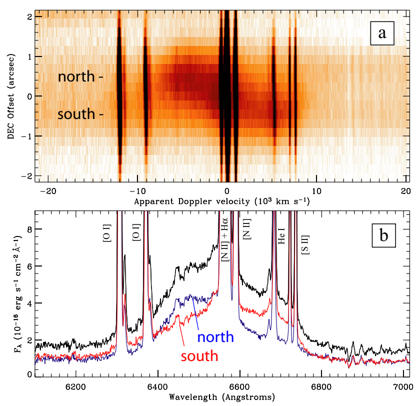
20 years after the explosion, the blast wave from SN1987A has now reached and is plowing through the circumstellar ring. Protrusions caused by Rayleigh-Taylor instabilities in the ring were hit first by the blast wave, giving rise to a series of "hotspots" around the ring. Here we study the emission line profiles of the shock-heated gas in these hotspots.

OBSERVATIONS

We present high resolution (R=60,000) ground-based spectra of the inner equatorial ring of SN1987A.

We used the Phoenix spectrograph on Gemini South to observe He I λ10830 in April 2006. We used a 0.5"-wide slit aperture oriented as shown in the image, sampling emission from the blueshifted (north) and redshifted (south) sides of the equatorial ring. This is the first high-dispersion spectroscopy of He I λ10830 since the blast wave reached the ring.

We used the cross dispersed echelle spectrograph MIKE at the Magellan Observatory to obtain optical spectra of the ring as well in March 2005. Here we focus on emission from Hα and [N II] λ6583.



THREE VELOCITY COMPONENTS

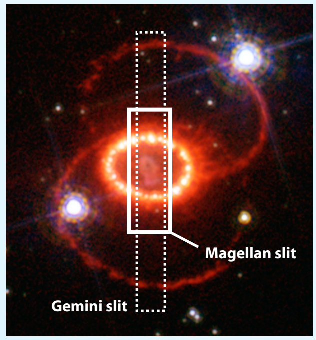
The interaction between the blast wave and the circumstellar ring gives rise to Hα emission with three main velocity components:

1. Very broad (-10,000 to 10,000 km/s) emission that traces H atoms crossing the **reverse shock.** This is seen in the low resolution spectrum above (from Smith et al. 2005, ApJ, 635, L41). It shows blueshifted emission to the north and redshifted emission to the south - the same pattern as the ring.

2. The narrower emission components above actually contain two separate components. The first is broad emission (few hundred km/s) from gas in the ring that has passed through the **forward shock**.

3. The last is a very narrow component from photoionized **circumstellar gas** in the ring that has not yet been hit by the forward shock, but is photoionized by UV emission from the shock itself.

The last two components cannot be easily resolved from one another in low-resolution spectra, but they can with R=60,000 echelle spectra presented here.



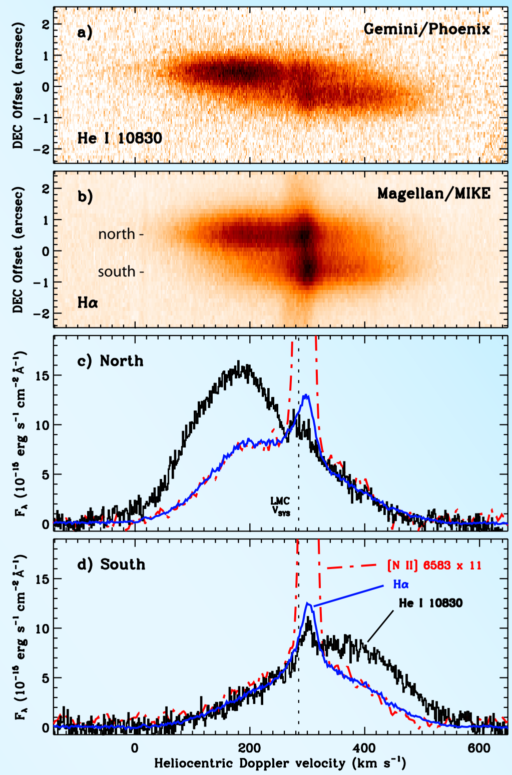
EMISSION FROM THE HOTSPOTS

Panels A and B in the figure at right show 2-D spectra of He I λ10830 and Hα, respectively. The two sides of the ring are clearly resolved from one another, even at ground based resolution. The north side of the ring is blueshifted, the south is redshifted.

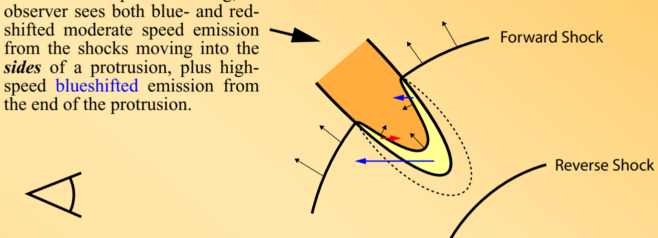
Panels C and D show extracted line profiles for the north and south sides of the ring, respectively, for He I λ10830, Hα, and [N II]. Main points to note:

1. Narrow emission from unshocked circumstellar gas is strong for [N II], but much weaker for Hα, and nearly absent for He I λ10830.

2. The broad components of Hα and [N II] have identical line profiles, but **He I line profiles are very different.** He I λ10830 has enhanced emission at high speeds - stronger blueshifted emission to the north and stronger redshifted emission to the south.



In the NORTH part of the ring, an observer sees both blue- and red-shifted moderate speed emission from the shocks moving into the ***sides*** of a protrusion, plus high-speed blueshifted emission from the end of the protrusion.

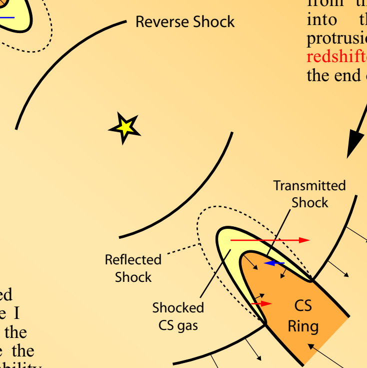


In the SOUTH part of the ring, an observer sees both red- and blue-shifted moderate speed emission from the shocks moving into the ***sides*** of a protrusion, plus high-speed redshifted emission from the end of the protrusion.

In this scenario, we can understand the difference between He I λ10830 and Hα line profiles if the He I emission is enhanced in the gas at the end of the protrusion that was hit by a faster shock (the longer red and blue arrows). The faster shock speed there causes higher ionization, enhancing the He I emission relative to Hα. N+ ionization follows H+.

The enhanced He I emission at the end of the shocked column, plus the extreme weakness of the narrow He I emission from unshocked CS gas (less than 5% of the total) means that He I images of the hotspots trace the strongest shocks in the CS gas. A comparison of variability between Hα and He I images can therefore give important clues to the geometry of the shock front.

The ring will brighten dramatically in He I emission in the near future, when the forward shock engulfs the full area of the ring.



Narrow lines come from the unshocked CS ring gas photo-ionized by the shock.